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VOL. III. NO. 25. DECEMBER 6, 1906.

THE JOURNAL OF PHILOSOPHY
PSYCHOLOGY AND SCIENTIFIC METHODS

A DEFINITION OF EXPERIMENTATION

THE question of the meaning of experimentation is brought repeatedly before us, if we read any criticisms of method by the scientific investigators themselves, or, indeed, if we stop to consider the reason for the terms and subdivisions of the different sciences and to ask why experiment plays so large a part in some and is so little used in others. Such phrases as 'the treacherous path of speculation instead of the safe way of observation and experiment'[1] or as 'those experimental investigations upon which the growth of science depends,'[2] and the sad note in the statements made by a distinguished geologist that 'there has been during the last few years a large accumulation of geological evidence, a little new speculation, but practically no new experimental work,'[3] and that geology is 'only beginning to enter the experimental stage';[4]—these, and the many other similar references to be met with, all suggest that for some reason the ideal of science is to build on experiment primarily if not entirely.

When we ask what experimentation is or what an experiment is, and much more when we ask how it is that experiment achieves its result, the answers are not so easy to find as we might hope, particularly if we turn for them to the scientific investigators themselves. Experimentation and observation together make up our means of appeal to the external world. That is clear. They connect us in some way with the phenomena there, make us master in part of that world of fact that yet we never feel as within our control. What, however, is the distinction between the two, how are we to tell an experiment from an observation? Dr. L. F. Barker, of Johns Hopkins University, stated in his address before the Massachusetts Medical Society in June, 1905, that their difference was one of relative exactness. In the report of another physician, we have again the phrase 'exact experimental evidence.'[5] But Lord Kelvin seems to refer to something different from exactness in saying 'their eyes to observe accurately and their hands to experiment, in order to learn more than can be learned by mere observation.'[6] Experiment to him promises new rather than merely more exact knowledge. Pasteur's statement that experimentation 'demands besides certain natural qualities a long practise which naturalists have not generally acquired nowadays'[7] is rather non-committal, but certainly does not give exactness as the unique achievement of the experiment. Huxley is satisfied to call it 'observation under artificial conditions,'[8] which is perhaps something like what Titchener means in defining experiment as 'simply an observation made under standard conditions,'[9] but it is certainly not a mere repetition of the demands either for measure and exactness or for the use of one's hands. We have, finally, Mill's well-known statement that "we may either find an instance in nature suited to our purposes, or, by an artificial arrangement of circumstances, make one. There is, in short, no difference in kind, no real distinction between the two processes of investigation (observation and experiment). There are, however, practical distinctions.'"[10]

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[1] Carl Schorlemmer, 'Rise and Development of Organic Chemistry,' p. 4.

[2] Thomas H. Huxley, 'Collected Essays,' Vol. I., p. 55.

[3] *Nature*, August 24, 1905, p. 408.

[4] *Ibid.*, p. 413.

The demand for a clear understanding of the word experiment in the physical sciences is made stronger when we remember that its use is not confined to those. The mathematician and logician insist that they, too, experiment when, for instance, they try number after number as the root of a given equation or develop the result of one after another of all imaginable combinations of postulates in the search for a new one that is useful and significant.

The suggestions at definition are purposely taken from a rather wide range of time and fields of investigation. The fact that they are not in obvious agreement does not surely mean that their authors held ideas of the proper use of the word experiment which were fundamentally different. It is possible that an investigator in a given field might take a characteristic of the result that could be gained only through experiment there as an invariable and necessary characteristic of experimentation in all fields. In the hope of bringing to light a common idea at the basis of all these special meanings for experiment, I have attempted to classify the methods of scientific investigation in such wise that experimentation should be exemplified in all the examples falling under one heading of my classification and in that way be contrasted with the methods belonging to the other headings. I use the term experimentation rather than experiment designedly because a new question enters if we ask how the single experiment is distinguished from the group of experiments or phase of an experiment.

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[5] J. J. Kilyoun, 'Bacterial Content of Railroad Coaches,' July, 1905.

[6] Lord Kelvin, 'Popular Lectures and Addresses,' Vol. II., p. 478.

[7] René Vallery-Radot, 'Life and Works of Pasteur,' translated by Lady Claud Hamilton, Vol. I., pp. 125-6.

[8] *Loc. cit.*, p. 66.

[9] E. B. Titchener, 'Primer of Psychology,' p. 26.

[10] J. S. Mill, 'A System of Logic,' Vol. III., Chap. VII., § 2.

The classification I finally adopted is the following. The comments which follow the classification may perhaps make its underlying principles clearer. It will be seen at once, however, that the different classes are not mutually exclusive, that is, the examples are chosen only because each calls for the unique element of method which that heading names. Application of any one of these methods would usually involve the use of some other as well.

A classification of methods used in the physical sciences in gaining data from experience with the natural world:

A. *Observation of the outside.*—The investigator does not consciously and voluntarily interfere with the phenomena he studies. I. Simple observation. The investigator merely observes as does the 'every-day' man. II. Complex observation. The investigator supplements the range of his sense organs. Examples: use of microscope, telescope, stethescope, X-ray machine; dragging the bottoms of lakes and oceans; bringing a compass near a magnet; spreading sand over a membrane to observe a faint sound vibration. III. Measure. The investigator supplements his powers of accurate comparison. Examples: measurement of length, time, strength of sound by modified stethescope; counts of number of bodies of different sorts in a drop of blood; counts of number of stars in a given region of the sky. IV. Transference (in position and by copymaking). The investigator supplements the accuracy of his memory or serves his greater convenience. Examples: moving specimens into the light; making photographs; making accurate drawings; staking out the outline of bands that precede the eclipse of the sun; use of the needle and smoke drum; use of preservatives for specimens.

B. *Observation of the inside.*—The investigator consciously and voluntarily isolates certain aspects of phenomena from their natural surroundings on the assumption that he keeps those aspects essentially complete and undisturbed. I. Material classification. The investigator isolates certain portions of a total experience, with the hands. Example: dissections. II. Mental dissections. The investigator isolates certain aspects of a total experience. *a.* Record-taking. By confining his attention to a portion of the qualities or conditions present. Examples: medical records; geologists' notes as to the fauna and flora present in a given country. *b.* Diagram-making. By confining his attention to some of the relations presented. Example: diagrammatic drawings of structure made by the anatomist, the zoologist, the crystologist.

C. *Experimentation.*—The investigator consciously and voluntarily alters the conditions of the phenomena studied.

According to this classification the distinction to be made between observation, on the one hand, and experimentation, on the other, is, as Mill says, not one 'in kind,' but a 'practical' distinction only.

A good typical instance of experimentation of least complexity is found in the case of Pasteur's experiment upon the condition of air in different places.[11] He arranged a number of sealed flasks containing some substance in which bacteria thrive. These he opened in turn to the air at different points, some in the low country and some high among the snow peaks of the Alps. He afterwards examined the contents to discover at which spots, if any, the air which had entered the flasks had not brought with it bacteria. Such a set of processes is an experiment, because the conditions which the substance within the bottles met were made distinctly artificial. Pasteur did not find substances isolated, exposed to the atmosphere at a single given spot and then isolated again. True, he himself did not touch the contents of the bottles directly in altering their conditions, but yet he did so indirectly by removing and replacing their seals. Experimentation in many cases calls, of course, for much more elaborate apparatus.

Such processes are to be contrasted with the two kinds of observation. First, with those methods which, however elaborate, are used with the intention merely of getting a better view of the object. So far as that particular object is concerned we might imagine here that the investigator's hands are tied behind his back. Besides the careful watching needed as an element in all investigation this class includes the use of various magnifying and measuring instruments and similar contrivances, and as well different forms of copying, I think. All photographs do not stand on the same basis here. For the geologist they serve as illustrations for communication and thus are not a part of the methods of science, but rather of its means of promulgation. The photographs of the astronomer, however, are taken not that he may show some one else what he has seen, but that he may himself compare the condition of a part of the heavens on one night with its condition on another, and that he may make measures to determine the size of the stars and their relative positions at his leisure and in a convenient manner. He uses the photographs and gains more from them than he could have gained, at least with the same amount of effort, from direct observation.

The name of the group representing the second form of observation would be dissection but that, as a pathologist suggested to me, many dissections are performed with the avowed purpose of creating specific artificial conditions in the subject examined. With vivisections, for instance, this is generally true. 'Material classification' was suggested by Dr. Royce as following Kemp's assertion that the essence of classification is the marking a group of things off from others unlike them, rather than the binding of like objects together. There we have the motive of this second kind of observation at work. In order to study them more closely we separate the heart and lungs of a rabbit, for instance, from their natural surroundings.

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[11] *Loc. cit.*, pp. 127–8.

By the records referred to something is meant other than the descriptions used continually in communicating results. When the physician records he notes only certain aspects (such as temperature, pulse, etc.) which he considers significant, and entirely ignores other aspects of the patient (such as complexion and height, perhaps), assuming that they have no bearing on the nature and cause of the disease. As a result he gives us only, as it were, a skeleton, or perhaps the breath or the heart of a man, with no suggestion as to how these scraps are to be filled out to reproduce the original he studied. In the descriptions made purely for the sake of communication details are often omitted, but there they are left unstated either because, as perhaps with colors, they are implied in the names of the trees and the rocks given or because the writer himself has forgotten them. In making records the investigator is conscious that what he gives can not be found by itself, just as a nerve can not be found except it be taken from an animal body. In his record he isolates aspects of the situation before him from the other conditions that invariably accompany them, and believes that none of the relations annulled by such isolation have any influence upon the aspects he does report.

The classification may be objected to as a whole on the ground that these classes which I have distinguished from each other are not really distinct, so that many true cases can be produced as evidence of its insufficiency. In what I call simple observation, for instance, the mere fact that our attention is centered upon one part of the field rather than another alters the aspect of that field somewhat. We can not be sure in any given instance that we do not interfere with the object we study. It is true, also, that no one who has read of the weeks of drill and the great precautions taken against jar and dust at the time of making observations of the eclipse of the sun in August, 1905,[12] or of the care with which an astronomer must adjust his telescope and ward against imperfections in its action[13] can feel that the scientist finds it an easy matter to be sure that he perceives the phenomenon exactly as it is, by means of his reenforced sense organs. Measures, too, must be made with great care, often with the aid of microscopes, and must be revised as new and more accurate instruments are invented. It would seem to take fully as much effort and thought and preparation to guard against interfering with the natural course of phenomena as to plan just how one should interfere. We must, as it were, greatly interfere with our own natural course of action in order to guard against intruding ourselves upon the object we observe. The same thing is, of course, to be said, perhaps with more force, in the case of all dissections. In isolating the specimen we have the greatest difficulty in keeping it intact. For these reasons the subjective qualification is introduced into my definition, the qualification that the interference must be conscious and voluntary. Whenever the investigator believes that he has not interfered, he observes.

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[12] *Nature*, September 7, 1905. Letter by W. J. L. Lockyer.

[13] Cf. 'Annals of the Astronomical Observatory of Harvard College,' Vol. XXVI., Pt. I.; Vol. XVIII., No. VII.

The line cases and the complex cases which can be pointed out are many; so, too, are the perplexing cases that can be classified only after a more careful examination. The large number of line cases suggests, what I must readily admit to be true, that their proper name is borderland cases,—that the division between the classes is made by a stretch of neutral territory rather than by a definite narrow fence.

We have, for instance, an investigation which Lord Kelvin describes that offers some difficulty.[14] In this the experimenter placed his head between the poles of a horseshoe magnet to determine whether he would become thus directly aware of the condition which made a piece of copper slip through the space 'as if through mud.' The pure observer goes to a selected spot to watch the action there. The operation in this instance could be so described. The investigator put his head in a certain spot in the hope that he might observe the conditions there. What this investigator wishes, however, is to learn the effect of certain conditions upon his nerves (or muscles, perhaps) other than those of the senses which are properly called into play in simple observation. He plays a double part, as it were. He puts himself in the particular spot more that he may, if possible, become affected by the conditions there than that he may watch the play of those conditions among themselves as the geologist watches the eruption of a volcano. Thus this would seem to me to be an example of experimentation.

For a different reason the case in which Malus held the crystal up to observe its effect upon reflected light is perplexing.[15] He altered the place of the crystal and so brought light to play upon it. When the zoologist pulls his subject into a better light as he dissects it, or reflects light upon a microscope slide, we should not say that he thereby experiments upon it. Malus placed his crystal in the light and looked through it, much, it would seem, as one looks through a microscope. That he might have chanced to lay it on a window in such a way that the same effect was produced, and might then have observed the effect, does not, it is true, bear on our point because in such chance action the change of condition would not have been both consciously and voluntarily brought about. But that he merely consciously and voluntarily changed its relation to light seems hardly enough to warrant calling the operation experimentation. The fact that the light was known to be reflected and not direct sunlight, however, and the fact that crystals and light react on each other in a manner not true in regard to animal bodies and light, introduce a sufficient element of really changed conditions to make it seem best to me to class this as on the borderland between experimentation and simple observation.

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[14] *Loc. cit.*, pp. 127-8.

[15] 'Life and Works of Pasteur,' as given, Vol. I., p. 345.

We have also to consider the references made by Wüllner in his section on acoustics[16] to general experience with musical instruments as to the effect of different sorts of bows, bridges and hammers upon the nature of sound. Musical instruments were by no means made for the purpose of testing the principles of acoustics. It is entirely immaterial to the experimenter whether he produces the sound or whether he chances to note it during the performance of a concert. Yet the instruments themselves are very carefully and very artificially constructed, and serve the purposes of science so exactly that if they had not been manufactured for the purposes of the musician the scientific investigator would have perforce constructed something very similar, for himself. These operations again seem to lie in a stretch of neutral territory between simple observation and experimentation.

These few examples have indicated that the different classes of the forms of observation do not represent stepping-stones from simple observation to experimentation, as those would suggest who insist that the essential of experimentation is complexity of apparatus. We can find examples that are in a neutral field between practically each kind of observation and experimentation itself. The only necessity for experimentation is conscious and voluntary interference with the object studied. This may be made directly with our own hands or may be accomplished by means of apparatus of various kinds.

The claim which such a definition makes for general acceptance is that it offers a criterion for experimentation in all the fields of the natural sciences in which it is used, and rests on a characteristic of method which is significant and is not brought out by any other term we have. Further, the definition is in general agreement with most of the cases in which the word is commonly applied, although some investigations that have been called experiments would fall under one of my two classes of methods of observation.

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[16] A. Wüllner, 'Experimental-Physik,' Vol. I., pp. 874–5.

It may be added that if such a definition of experimentation in the physical sciences is justified, the use of the term in psychology consistent with its use in these other sciences would not be limited to the field of accurate measurements. Those who insist that the psychological laboratory should be the place for such investigations only, might insist that all other investigations were necessarily imperfect and unfruitful, but they could not refuse to call them experiments.

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LINGUISTIC ABILITY AND INTELLECTUAL EFFICIENCY[1]

THE factors that go to make up an individual's general intellectual efficiency are perhaps too numerous and too complex for separate treatment by the experimental psychologist, if they do not even defy analysis by him. We generally assume that we can gauge with greater or less accuracy the mental qualities of an individual by a certain amount of purely empirical observation, but the exact sources of our judgment we often find difficulty in stating in a logical manner. An elementary distinction may be made as between intelligence and intellectuality; the former as an inherent quality and the latter rather as a matter of temporary information, for we often conceive of intelligence as the native aptitude for acquisition, and of intellectuality as representative of the amount acquired. Of course, the two are far from necessarily correlated. Whether or not the factor of intelligence, under this definition, be measurable, the writer hopes to discuss at some future time; the present experiments deal purely with the second quality, and then only with reference to actual and not at all to potential conditions.

Now if it be indeed impossible to subject to analytical experi-

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[1] A report of an investigation begun in the spring of 1906. As it is not probable that the writer will have an opportunity to recur to this problem in the near future it has seemed best to publish the obtained results as they stand.